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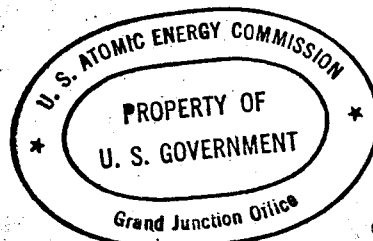
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DIAMOND AND WAGON DRILLING ON COVE AND EAST MESAS,
APACHE COUNTY, ARIZONA

By

J. W. Blagbrough, W. L. Chenoweth, and N. J. Clinton

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DIAMOND AND WAGON DRILLING ON COVE AND EAST MESAS,
APACHE COUNTY, ARIZONA

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DIAMOND AND WAGON DRILLING ON COVE AND EAST MESAS, APACHE COUNTY, ARIZONA

ABSTRACT

The U. S. Atomic Energy Commission conducted four drilling programs in Apache County, Arizona, to investigate uranium-vanadium deposits of the Salt Wash member of the Morrison formation on Cove and East Mesas. On the Cove Mesa No. 1 project, under Contract AT(05-1)-155, conducted March to July, 1951, 586 wagon drill holes were drilled, totalling 40,974 feet. On the Cove Mesa No. 2 project, under Contract AT(05-1)-120, conducted March 1 to May, 1951, 23 core holes were drilled, totalling 2,569 feet. On the Cove Mesa No. 3 project under Contract AT(30-1)-1364, conducted in the fall of 1952, 198 core holes were drilled, totalling 12,712 feet. On the Cove Mesa No. 4 project, under Contract AT(05-1)-231, conducted in the summer of 1953, 651 wagon drill holes were drilled, totalling 41,015 feet.

This report concerns chiefly projects 3 and 4, although information on the other projects is presented insofar as it was used in conducting projects 3 and 4. Results are presented chiefly as figures and in the tables.

Isorad maps of the ore zones, constructed by the "area-under-the curve" method were useful in guiding the drilling, as were ore trends, sedimentary trends, and limonite.

Favorable ground was delineated from drilling on 100-foot centers by constructing subsurface isorad maps. Drilling on 50-foot centers was required to outline ore bodies.

Uranium-vanadium ore occurs in the interval from 20 to 100 feet above the base of the Salt Wash member. Deposits range from small pods to tabular bodies as large as 600 by 150 feet. Thickness averages 2 feet, and average grade is 0.19 percent U_3O_8 and 1.40 percent V_2O_5 .

INTRODUCTION

This report presents the results of 12,712 feet of diamond drilling under Contract AT(30-1)-1364 on Cove Mesa in the fall of 1952 and 41,015 feet of wagon drilling under Contract AT(05-1)-231 on Cove and East Mesas in the summer of 1953. For purposes of reference the diamond drilling is referred to as the Cove Mesa No. 3 project, and the wagon drilling as the Cove Mesa No. 4 project. Prior drilling was done on the Cove Mesa No. 1 project (Contract AT(05-1)-155) and on the Cove Mesa No. 2 project (Contract AT(05-1)-120).

Cove Mesa and East Mesa are in Apache County, Arizona, on the Navajo Indian Reservation about 25 miles southwest of the Four Corners area. The area may be reached by turning west off U. S. Highway 666 about 6 miles south of Shiprock, New Mexico, on to a graded road that leads to Cove School. Approximately 7 miles west of Red Rock Trading Post a truck road leads to Cove Mesa some ten miles to the northwest (fig. 1).

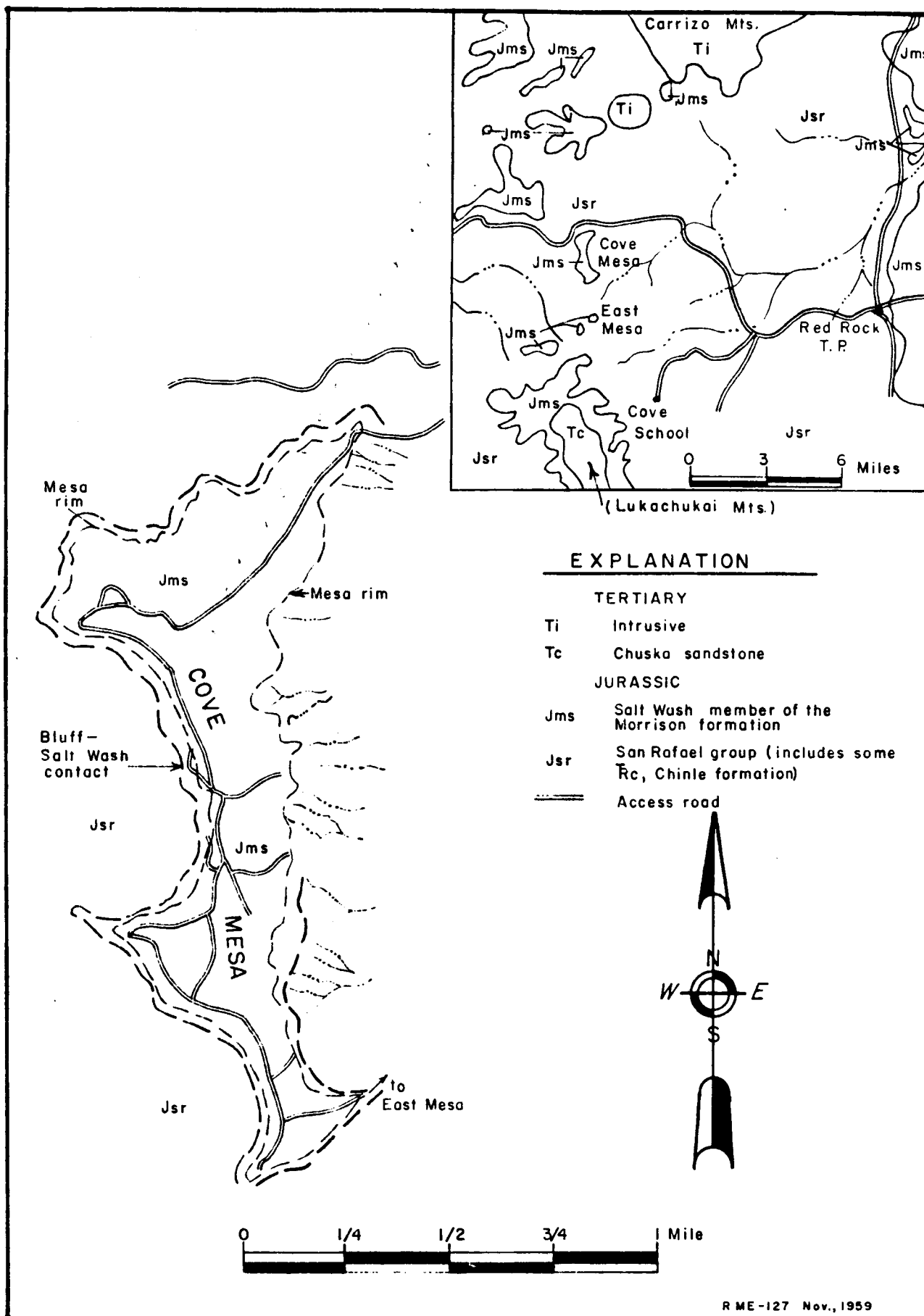


Figure 1. Location of Cove Mesa and East Mesa, Apache County, Arizona

Cove and East Mesas are erosional remnants, capped by the Salt Wash member of the Morrison formation, between the Lukachukai Mountains to the south and the Carrizo Mountains to the north. The surfaces of both mesas are nearly level, but with gentle slopes to the northwest. Elevations on Cove Mesa range from 6,800 to 7,080 feet above sea level. East Mesa is slightly higher with elevations of 7,560 to 7,600 feet. The mesa tops have dense growths of piñon and juniper.

The area west of Cove Mesa is drained by Chinle Wash, and the area to the east is drained by Red Wash; both of these washes are tributary to the San Juan River to the north. The San Juan River is the only perennial stream in the region. Water is obtained mostly from natural and developed springs in the area.

PREVIOUS WORK

Cove Mesa and East Mesa were first mapped and the ore deposits studied by D. C. Duncan and W. L. Stokes in October and November, 1942, and by Stokes and G. M. Sowers in April, 1945, as part of the strategic mineral program of the U.S. Geological Survey in the Carrizo Mountains area. A portion of their work was published by Stokes (1951). Geologists of the Union Mines Development Corporation, who evaluated the uranium resources of the Salt Wash member of the Morrison formation under the Manhattan project, were in the area from the fall of 1943 to the spring of 1944 and returned during the summer of 1945. They studied only the Salt Wash and described all of the uranium-vanadium deposits that crop out on Cove and East Mesas. Union Mines' work is summarized by Webber (1943) and Harshbarger (1946). Stokes (1953) studied the relationship of sedimentary trends to ore deposits on Cove and East Mesas as part of his studies in the Carrizo Mountains area.

Two drilling projects preceded the drilling reported here. The first, Cove Mesa No. 1, was done by percussion air drill with which 586 holes were bored for a total footage of 40,974 feet. Two hundred and fifty-six of these were on a pattern with 250-foot centers, a spacing which covered Cove Mesa entirely. The remaining 330 holes were offsets to holes of the first group which penetrated ore or mineralized rock. The offset holes were spaced 25 feet from the original holes. The Cove Mesa No. 2 project consisted of 23 widely-spaced cored holes for structural data, for a total footage of 2,596 feet. Project Nos. 1 and 2 were conducted in the first half of 1951. Some of the results are presented in this report, since data from the previous projects were used in planning the drilling in Projects 3 and 4.

GENERAL GEOLOGY

Stratigraphy

Sedimentary rocks ranging from the Triassic Chinle formation to the Jurassic Salt Wash member of the Morrison formation are exposed in the general area of Cove and East Mesas.

All of the mineralization in the area is in the Salt Wash member. The Salt Wash is generally 80 to 115 feet thick in the area and forms the steep irregular cliffs which bound Cove and East Mesas. However, owing to erosion, the complete Salt Wash section is not present on these mesas. The Salt Wash is a sandstone with minor amounts of mudstone and siltstone. The sandstone is light red to pale gray, fine- to very fine-grained, well-sorted, with rounded to subrounded quartz grains. It consists chiefly of imbricated lenses whose maximum thicknesses range up to 25 feet. These lenses are usually moderately cross-bedded and obscurely interfingered with flat, even-bedded, flaggy layers, some of which are ripple-marked. Locally it is well-cemented with secondary calcite. Red and green mudstone galls are common throughout the sandstone lenses.

The mudstone and siltstone lenses separating the sandstones range in thickness from a few inches up to 3 feet. They are gray, greenish-gray, or reddish-brown and commonly are somewhat mottled. Lenses are seldom longer than 200 feet and commonly pinch, swell, split, and coalesce along the bedding.

Fossil logs and carbonaceous materials are common throughout the Salt Wash on Cove Mesa. Fragmented particles and flakes of carbon form seams along the bedding. Finer particles of carbonaceous matter disseminated through the sandstone impart its typical bluish gray color. Abundant imprints of organic material are found on thin clay partings.

As would be expected in a fluvial unit such as the Salt Wash, cross-bedding, festoon-bedding, ripple marks, and current lineations are common.

Structure

Cove and East Mesas are in a broad syncline between the Carrizo and Lukachukai Mountains. To the north the sediments have been domed by the Carrizo Mountains intrusions. Southward they rise toward the Lukachukai monocline in the Lukachukai Mountains. Locally on Cove Mesa the beds dip northwest at angles from 2 to 3 degrees (fig. 2). Faults are absent from the area.

URANIUM-VANADIUM DEPOSITS

The uranium-vanadium deposits on Cove Mesa were discovered about 1918, but little mining was done until 1942, when World War II increased the demand for vanadium-bearing ore. After the demand for vanadium from domestic sources ceased in 1944 the deposits were unworked until 1948, when mining was resumed to produce both uranium and vanadium.

The ore is mined either by drifting in from the rim or by driving inclines from the mesa top to ore discovered by drilling. In the mines, rock pillars or timbers support the roofs. Mine cars are used to transport the ore in the larger mines. Currently (January, 1958) only two mines are being worked on Cove Mesa. Production has been small but continuous. As of January, 1958, 26,000 tons of ore averaging 0.22 percent U_3O_8 and 1.66 percent V_2O_5 had been shipped from Cove and East Mesas.

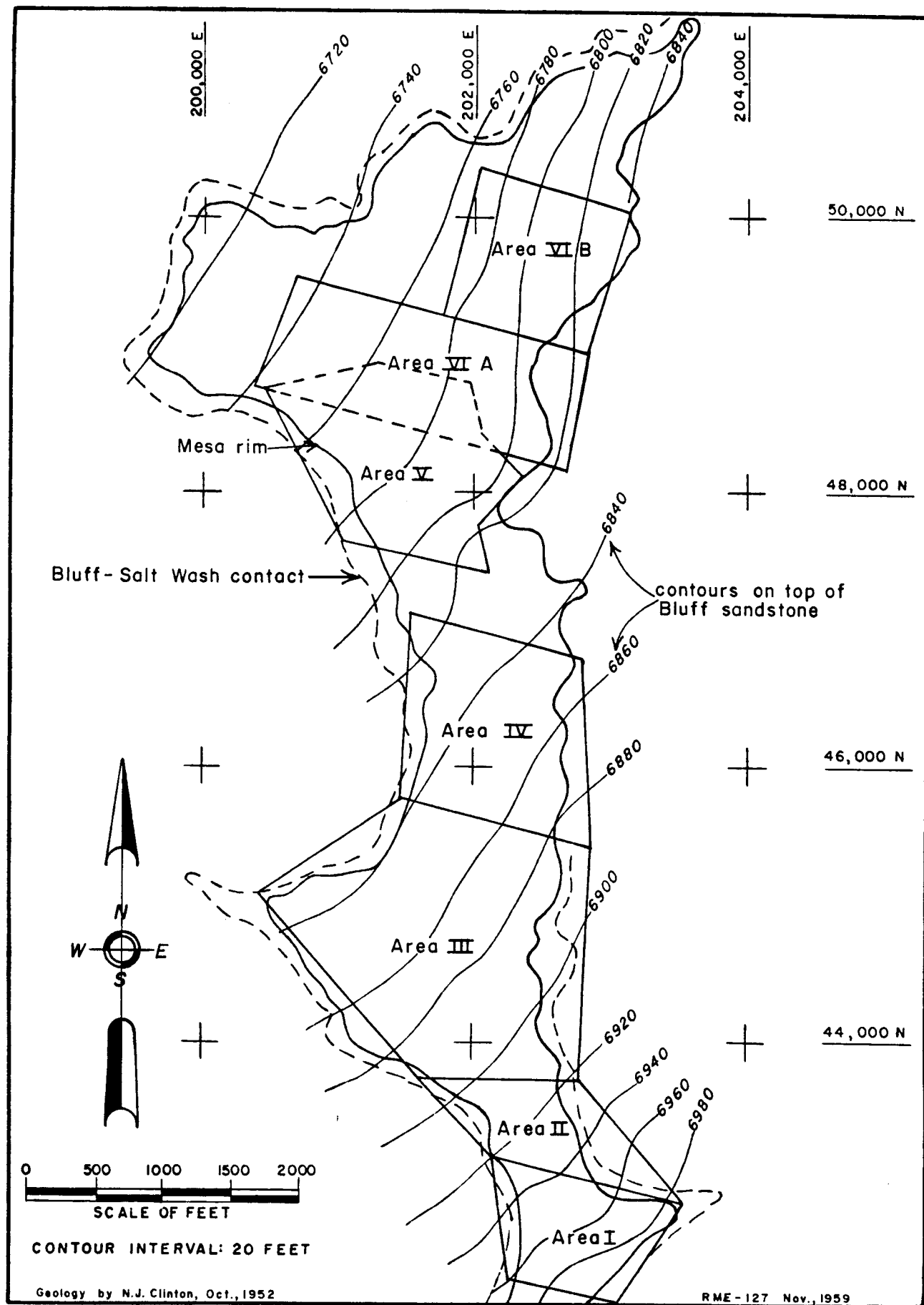


Figure 2. Index of drilling areas, and structure contours, Cove Mesa, Apache County, Arizona.

Both Cove and East Mesas are on the Navajo Indian Reservation and are under the jurisdiction of the Department of the Interior, Bureau of Indian Affairs. Mining permits and leases must be approved by the Navajo Tribal Council.

The southern two-thirds of Cove Mesa is a U.S. Atomic Energy Commission lease, having been withdrawn by Union Mines Development Corporation under the Manhattan Project. Vanadium Corporation of America of Durango, Colorado, has been assigned the lease. Cato Sells, a Navajo of Farmington, New Mexico, has a mining permit on the northern one-third of the mesa (fig. 9). Leroy Pettigrew of Shiprock, New Mexico, has a mining permit on East Mesa.

Ore is found in at least three levels in a zone 20 to 100 feet above the base of the Salt Wash. The ore minerals are metatyuyamunite, montroseite, vanadium clays, and partly to completely oxidized vanadium minerals. They occur as fillings of interstices, sand-grain coatings, and replacement of clay particles and carbonaceous material. Some logs are mineralized and run higher in uranium and vanadium than the surrounding rock. Calcite cement varies throughout the ore but is commonly present in such amounts that the ore is classed as "high-lime ore".

The deposits are generally tabular and conform to the sandstone beds; however, a few "rolls" occur that cut the bedding planes at low angles. Lateral terminations of ore vary from gradual thinning to abrupt termination. Ore bodies on Cove Mesa range in size from individual small pods to clusters of pods almost completely covering an area 600 by 150 feet. The average diameter of the ore bodies is about 150 feet, and the average thickness is about 2 feet. The grade averages about 0.19 percent U_3O_8 and 1.40 percent V_2O_5 . The small size of the ore bodies in this area makes closely spaced drilling necessary for blocking out ore.

The ore-bearing sands are gray, with associated greenish-gray mudstone and siltstone lenses and galls. Limonite flecks are common in the ore-bearing rock, and limonite is considered to be an ore guide in this area.

The largest deposits occur where there are changes in direction of the sedimentary trends as projected in from the rim (fig. 9). Although it is not certain that these areas are actual paleostream meanders, they are so termed in this report. It would be expected that concentrations of carbonaceous material would accumulate in the curves of meanders. Since plant debris is a common associate of uranium mineralization the accumulated debris might have aided in the localization of the deposits in meanders.

DRILLING

Drilling Guides

The principal drilling guides used in the Cove Mesa No. 3 diamond drilling project were isorad maps constructed from the Geiger logs of the Cove Mesa No. 1 drilling and from scintillation logs of the holes cored in the first phase of the No. 3 project. These maps showed several subsurface radiometric highs which were tested by holes spaced from 50 to 200 feet.

The isorad maps were constructed using the planimetric method, or, as commonly called, "the area under the curve" method. This method of using gamma-ray logs has been outlined by Hinckley (1952). The procedure is to planimeter the area under the gamma-ray curve for the ore zone. Mudstone beds within this unit are excluded. The total planimetered area is divided by the total sandstone thickness to obtain the figure which is used in the construction of the isorad map.

The principal guides employed in the Cove Mesa No. 4 project were the ore trends (fig. 9), sedimentary trends (fig. 9), and isorad maps constructed from the Cove Mesa No. 3 drilling (figs. 3 and 8). Projection of the trend of ore and of sedimentary features (cross-bedding, lineation, etc.) from the west rim through Cove Mesa to the east rim suggested that certain areas were favorable. Many of these areas had not been drilled sufficiently to disclose ore bodies, should they be present. Projection also indicated areas where there was a definite change in direction of sedimentary trends from one side of the mesa to the other. These changes or "meanders" were considered favorable places for uranium mineralization.

The isorad maps of the No. 3 project showed several subsurface radiometric highs in areas which had not been adequately drilled.

Cove Mesa No. 3 Project

Cove Mesa is divided into seven drilling areas (fig. 2) where 12,712 feet were cored in 198 holes in the Cove Mesa No. 3 project (table 1). Some of these, widely spaced, were drilled to the top of the Bluff sandstone for stratigraphic information. The others were drilled to explore subsurface radiometric highs located from the data of the Cove Mesa Nos. 1 and 3 projects.

Table 1

Summary of Cove Mesa No. 3 Diamond Drilling

<u>Area</u>	<u>Ore</u>	<u>Holes</u> <u>Mineralized</u>	<u>Barren</u>	<u>Total</u>	<u>Ft. Drilled</u>
Cove Mesa I	2	2	13	17	1,266
Cove Mesa II	0	0	10	10	890
Cove Mesa III	19	8	67	94	6,024
Cove Mesa IV	9	2	39	50	2,237
Cove Mesa V	0	1	14	15	1,325
Cove Mesa VI	0	0	12	12	970
Total	30	13	155	198	12,712

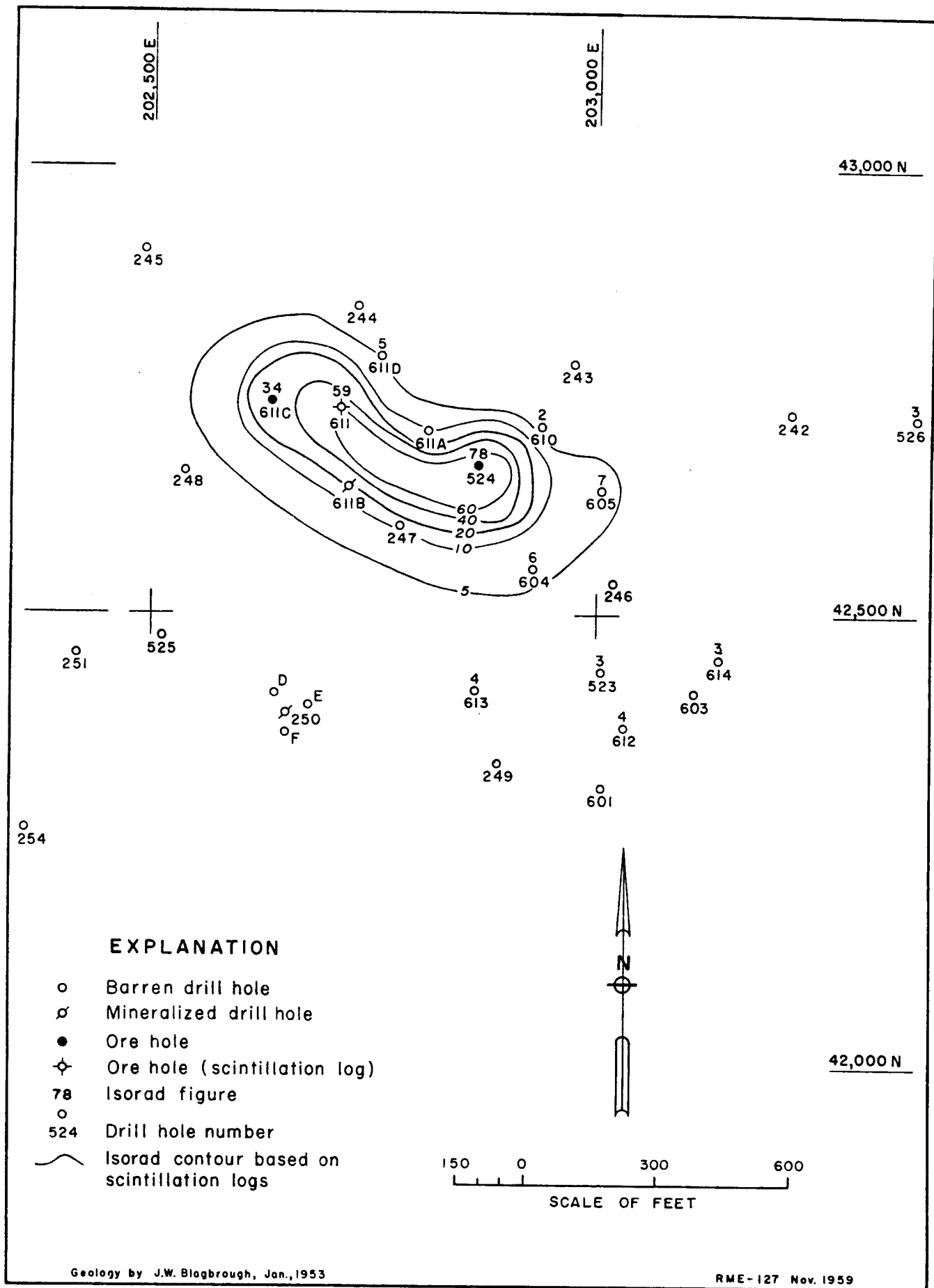


Figure 3. Isorad map of Area I, Cove Mesa, Apache County, Arizona

Isorad maps constructed from the Geiger logs of the Cove Mesa No. 1 project indicated favorable areas and determined the location of the initial holes. In Areas I, III and IV new isorad maps (figs. 3, 4 and 5) were drawn from Cove Mesa No. 3 scintillation logs, and these maps determined the position of further offsets. Composite isorad maps, using values from both the Geiger logs and the scintillation logs, could not be made, because the values from one type of log could not be converted to equivalent values of the other type of log.

In Areas I, III, and IV isorad maps based on holes spaced 100' apart were used successfully to delineate favorable ground. Some subsurface radiometric highs in Area III were further drilled by holes 50 feet apart; this spacing is considered necessary to locate ore bodies in this region.

Wagon drilling was recommended to prove favorable ground shown by isorad maps of Areas I, III, IV and V (figs. 3, 4, 5 and 6) and to determine ore trends and sedimentary trends in all seven areas of Cove Mesa.

Cove Mesa No. 4 Project

On the Cove Mesa No. 4 project 651 wagon drill holes were drilled, totalling 41,015 feet (Table 2). Drilling was done in three stages. In the first stage areas of high radioactivity, as shown by the isorad maps of the Cove Mesa No. 3 project, were drilled with holes spaced from 50 to 100 feet apart. Drilling in the second stage was guided by a map of ore trends and sedimentary trends. Favorable areas were selected and holes on 100- to 200-foot centers were drilled on alignments roughly parallel to the trends. The third stage consisted of offsetting ore holes at distances of 50 feet. Several of the Cove Mesa gamma-ray logs showed counts high enough for ore-grade material where the assay values were below ore grade. It was concluded that the inadequate sampling techniques used (Garcia, 1952), as well as assaying in 5-foot intervals, resulted in dilution of the cuttings so that any ore-grade material present would not be indicated in the assays. These holes were offset as part of the third stage, and a considerable amount of ore was found.

In Area I drilling consisted of closely spaced holes in an area of high subsurface radioactivity; these were drilled with holes on 50- to 100-foot centers. A portion of the rim on the west side of the mesa was judged to be favorable on the basis of several criteria, and widely spaced holes were drilled near this rim.

In Area II widely spaced holes were drilled near a favorable rim on the west side of the area. Offset holes were then drilled near the ore holes and mineralized holes, and the ore bodies were delineated.

For Area III an isorad map indicated several areas of high subsurface radioactivity; these were drilled with holes on 50- to 100-foot centers. A portion of the rim on the west side of the mesa was judged to be favorable on the basis of several criteria, and widely spaced holes were drilled near this rim. Area III was thought to include a large "meander" and widely spaced holes were drilled in several areas not adequately tested by previous drilling. Ore bodies were outlined by holes on 50-foot centers (fig. 9).

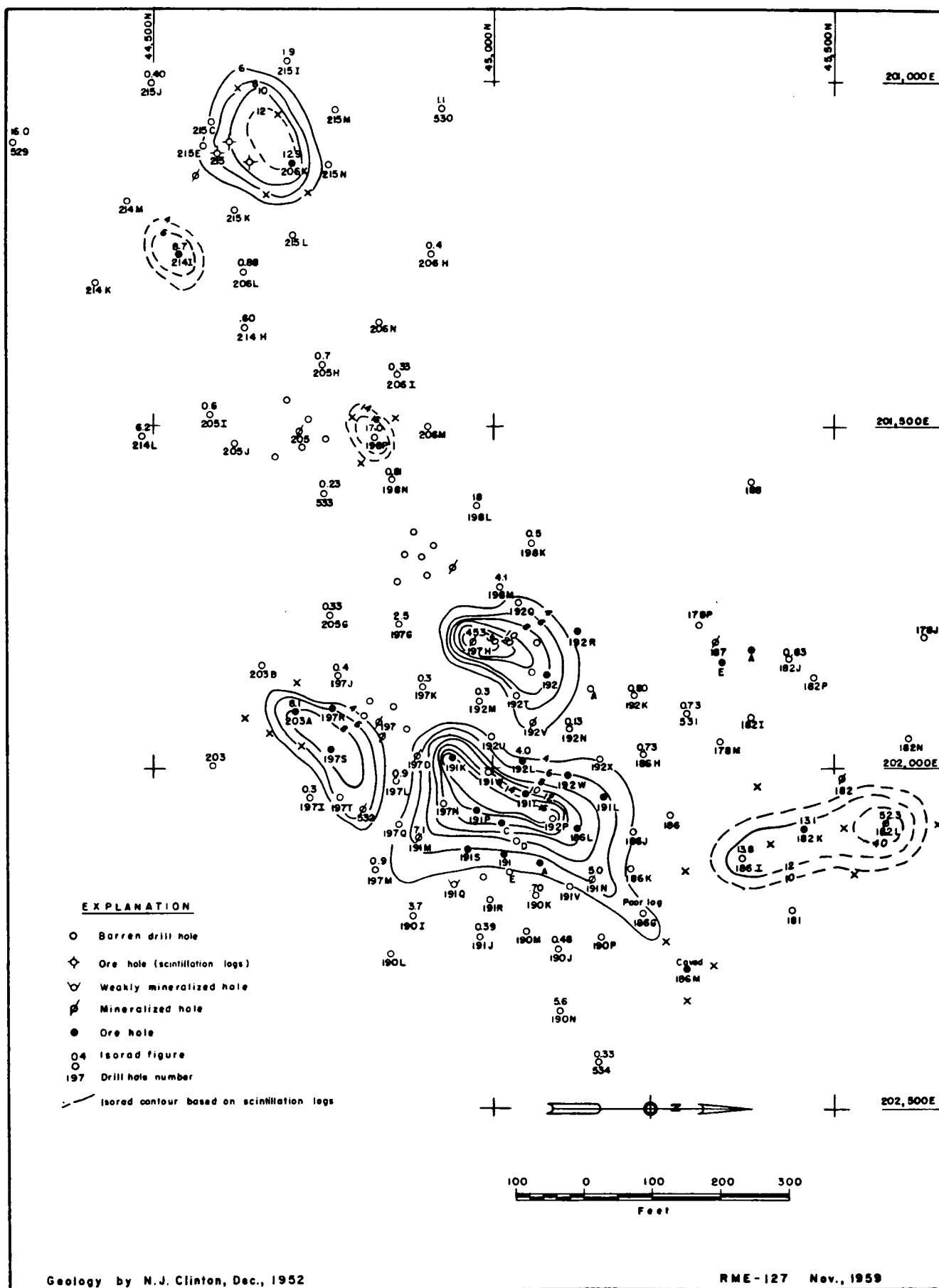


Figure 4. Isorad map of Area III, Cove Mesa, Apache County, Arizona

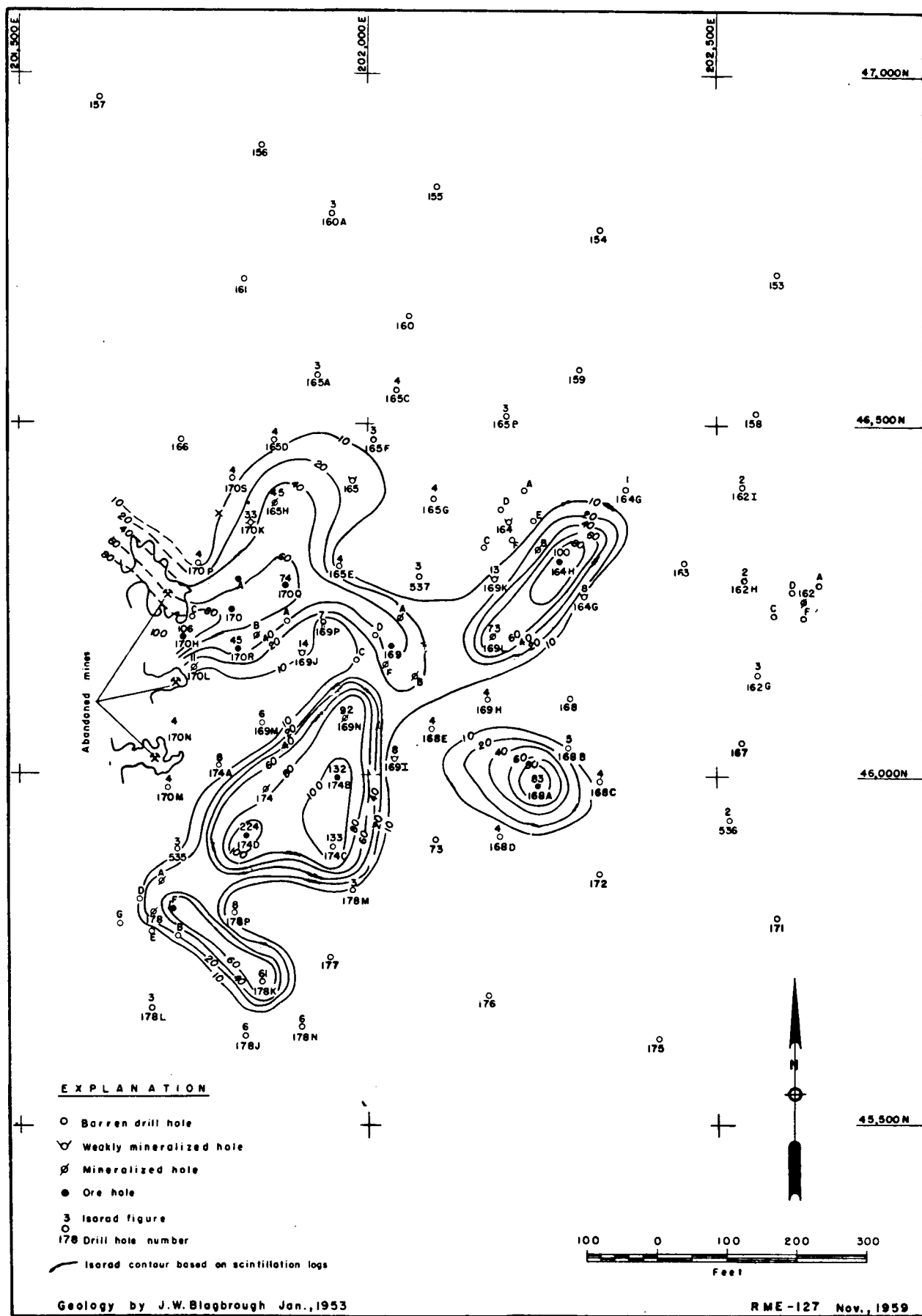


Figure 5. Isorad map of Area IV, Cove Mesa, Apache County, Arizona

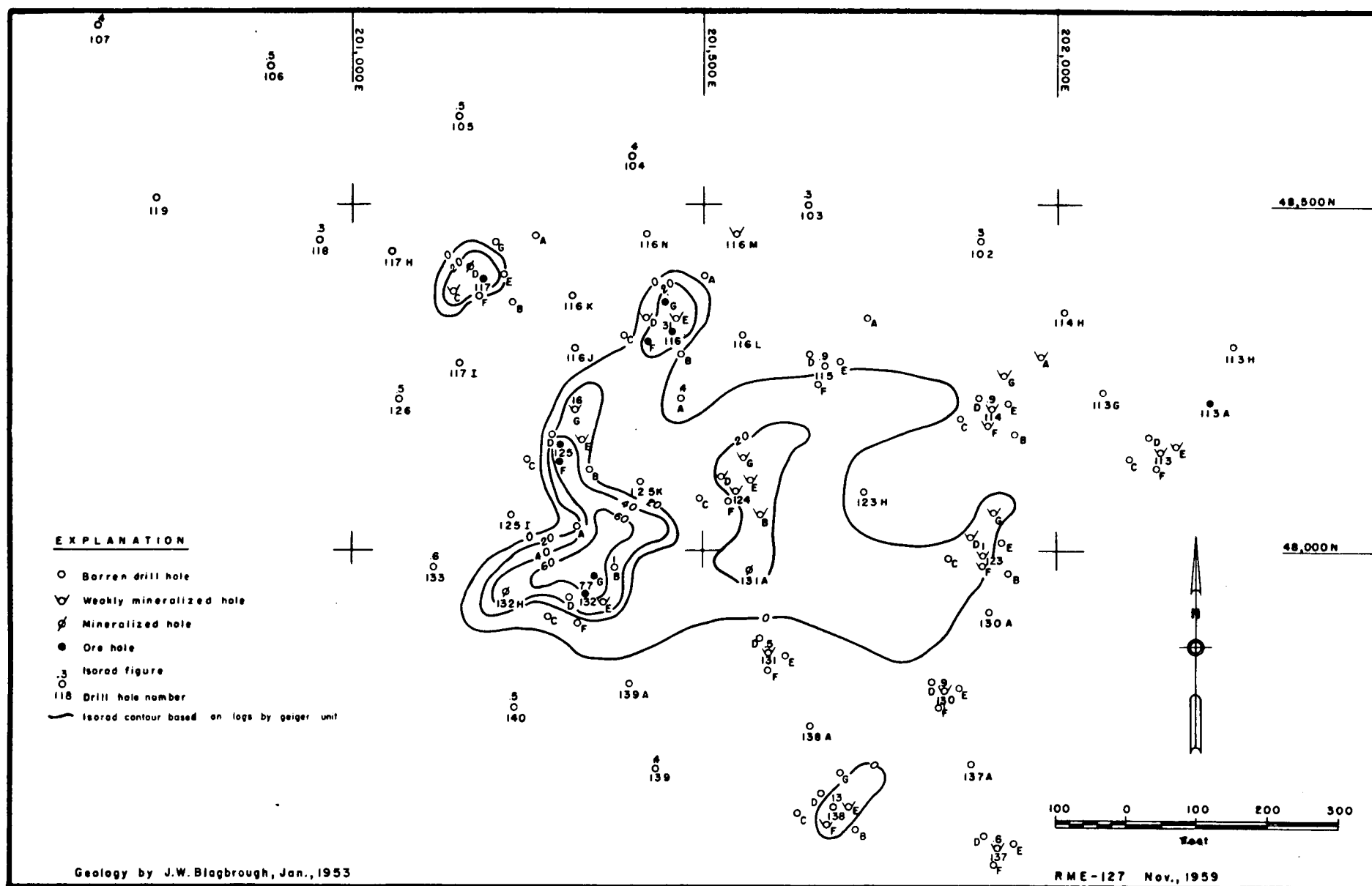


Figure 6. Isorad map of Area V, Cove Mesa, Apache County, Arizona

Table 2

Summary of Cove Mesa No. 4 Wagon Drilling

<u>Area</u>	<u>Ore</u>	<u>Holes</u>		<u>Total</u>	<u>Feet Drilled</u>
		<u>Mineralized</u>	<u>Barren</u>		
Cove Mesa I	21	6	37	64	3,855
Cove Mesa II	9	4	21	34	3,071
Cove Mesa III	43	21	79	143	7,371
Cove Mesa IV	29	27	96	152	5,965
Cove Mesa V	20	8	58	86	6,880
Cove Mesa VI	33	15	99	147	12,067
East Mesa	1	3	21	25	1,806
Total	156	84	411	651	41,015

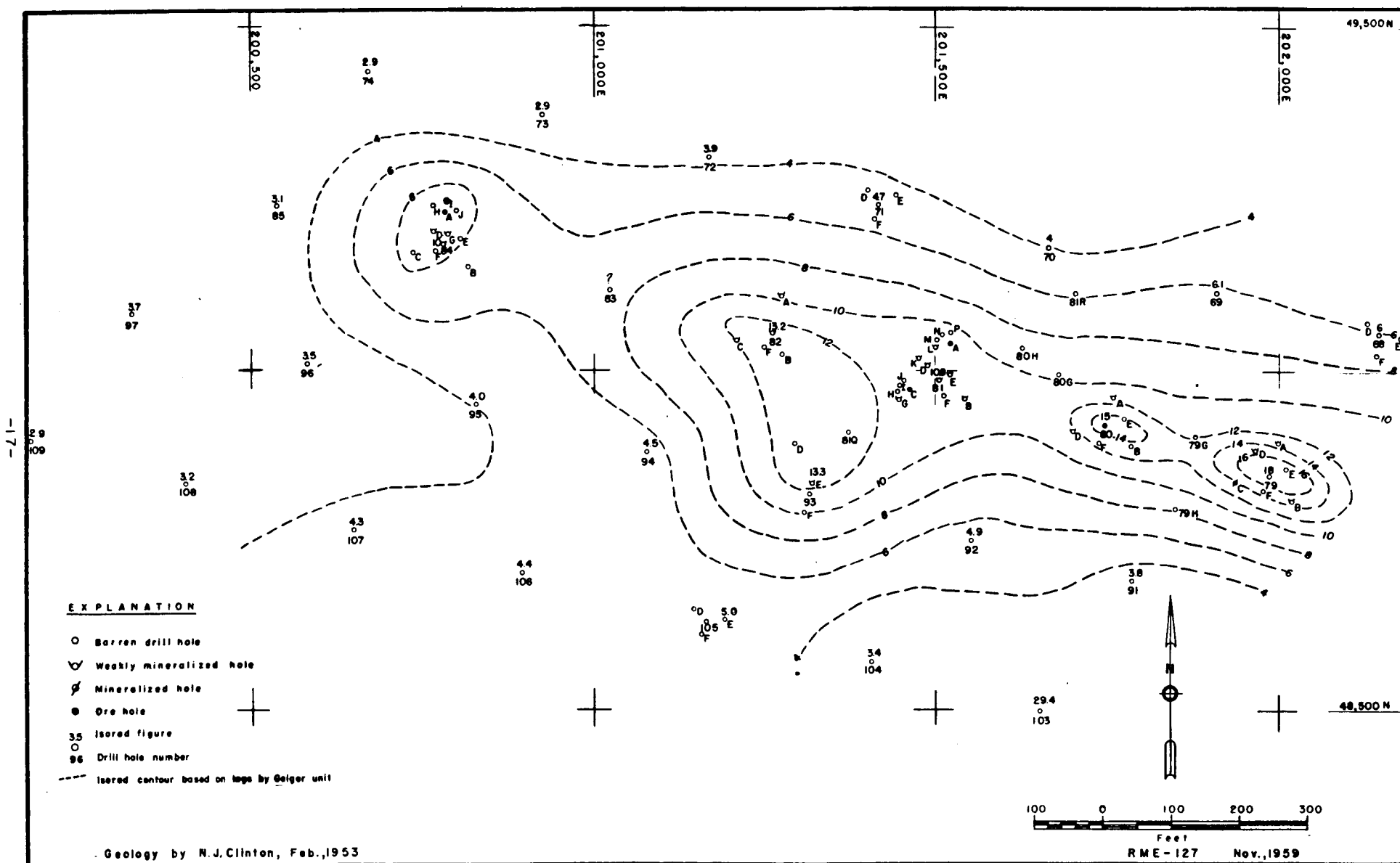
For Area IV an isorad map constructed from the results of the Cove Mesa No. 3 project indicated several areas of high subsurface radioactivity. These were drilled with holes spaced 50 to 100 feet apart. Near the east rim of the mesa an area was drilled using 100- to 150-foot centers, because the trend map showed it to be favorable ground. Ore bodies were outlined by holes on 50-foot centers.

In Area V several areas of high subsurface radioactivity, as shown by an isorad map, were drilled on 50- to 100-foot centers. Ground judged to be favorable was drilled with widely spaced holes. Ore bodies were outlined by holes on 50-foot centers.

The rim map (fig. 9) showed that a "meander" was probably present in Areas VIA and VIB. Isorad maps from the Cove Mesa No. 1 gamma logs (figs. 7 and 8) indicated an elongate arcuate zone of high radioactivity, and this zone was believed to be roughly coincident with the "meander". Widely spaced holes were drilled in the area of this zone. Several ore bodies were found, and these were outlined with holes on 50-foot centers.

On East Mesa holes spaced from 100 to 200 feet apart were drilled near favorable rims. A few investigative holes were drilled away from the rim as a test of the potential of the mesa.

In order to compare the lithologic logs made from both core and non-core holes, tests were conducted during the No. 4 project. Three core holes from previous projects were selected, and within 3 feet of each hole two wagon drill holes were drilled, one on each side of the hole. Cuttings from the



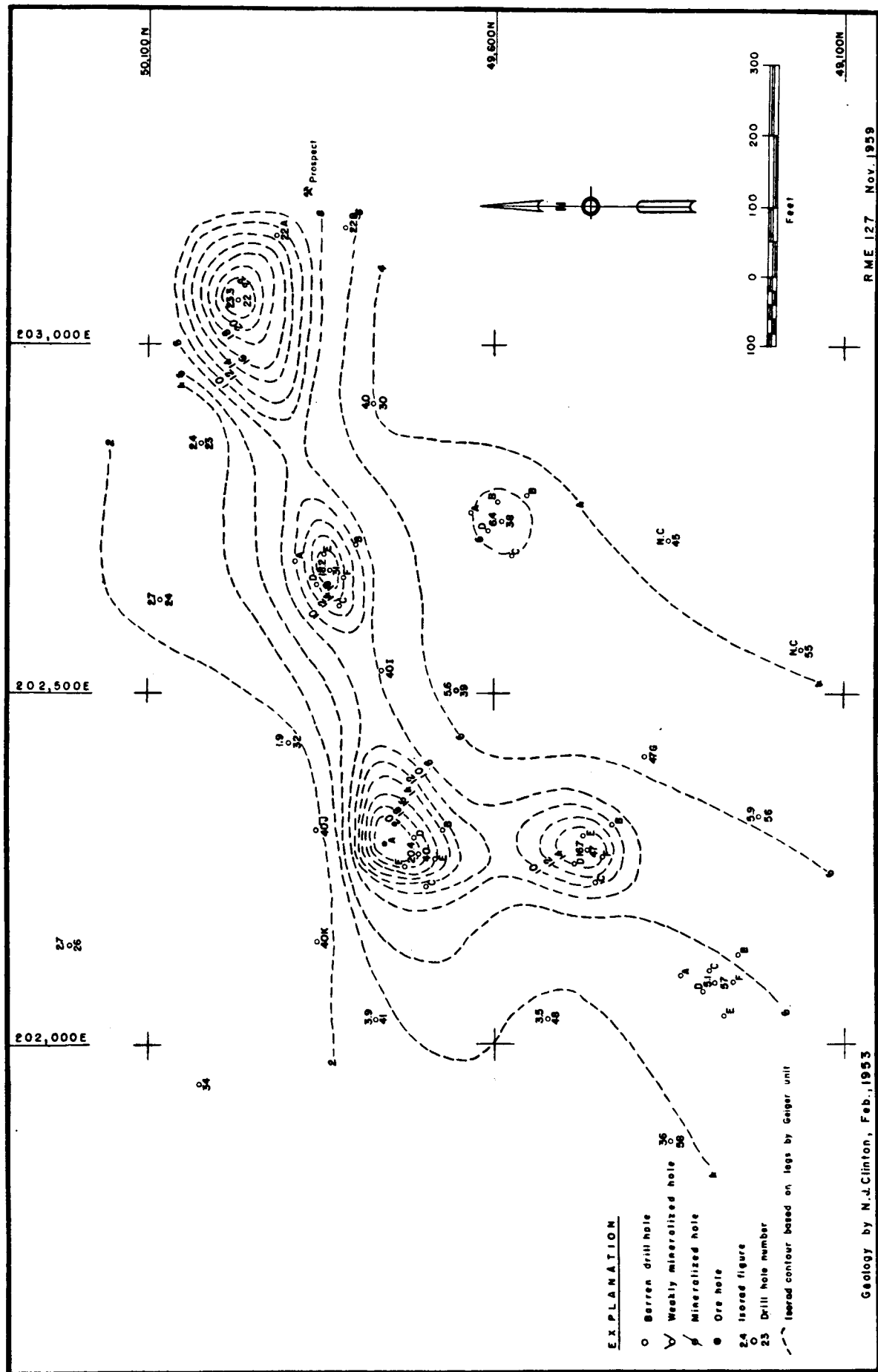


Figure 8. Isorad map of Area VI-B, Cove Mesa, Apache County, Arizona

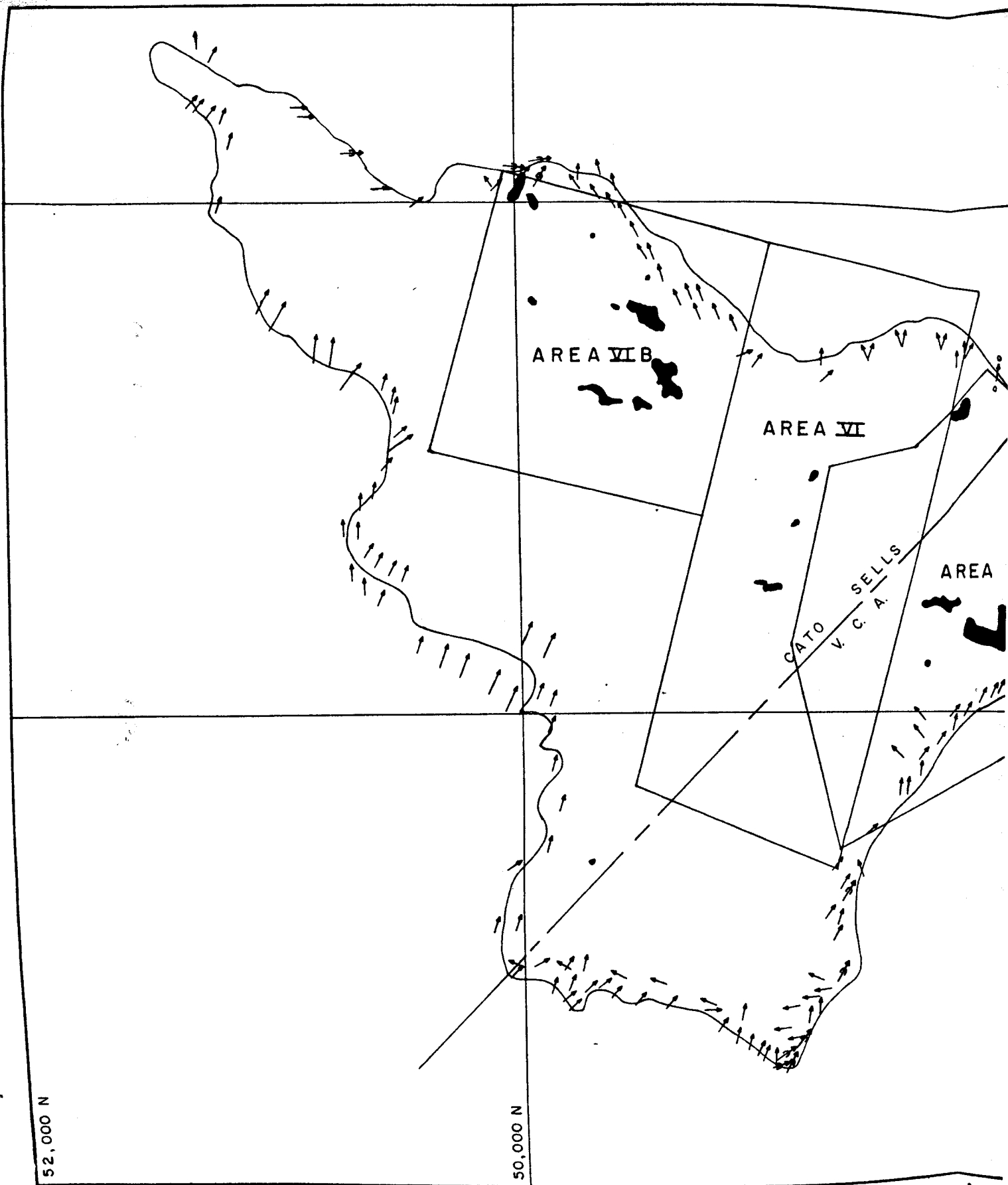
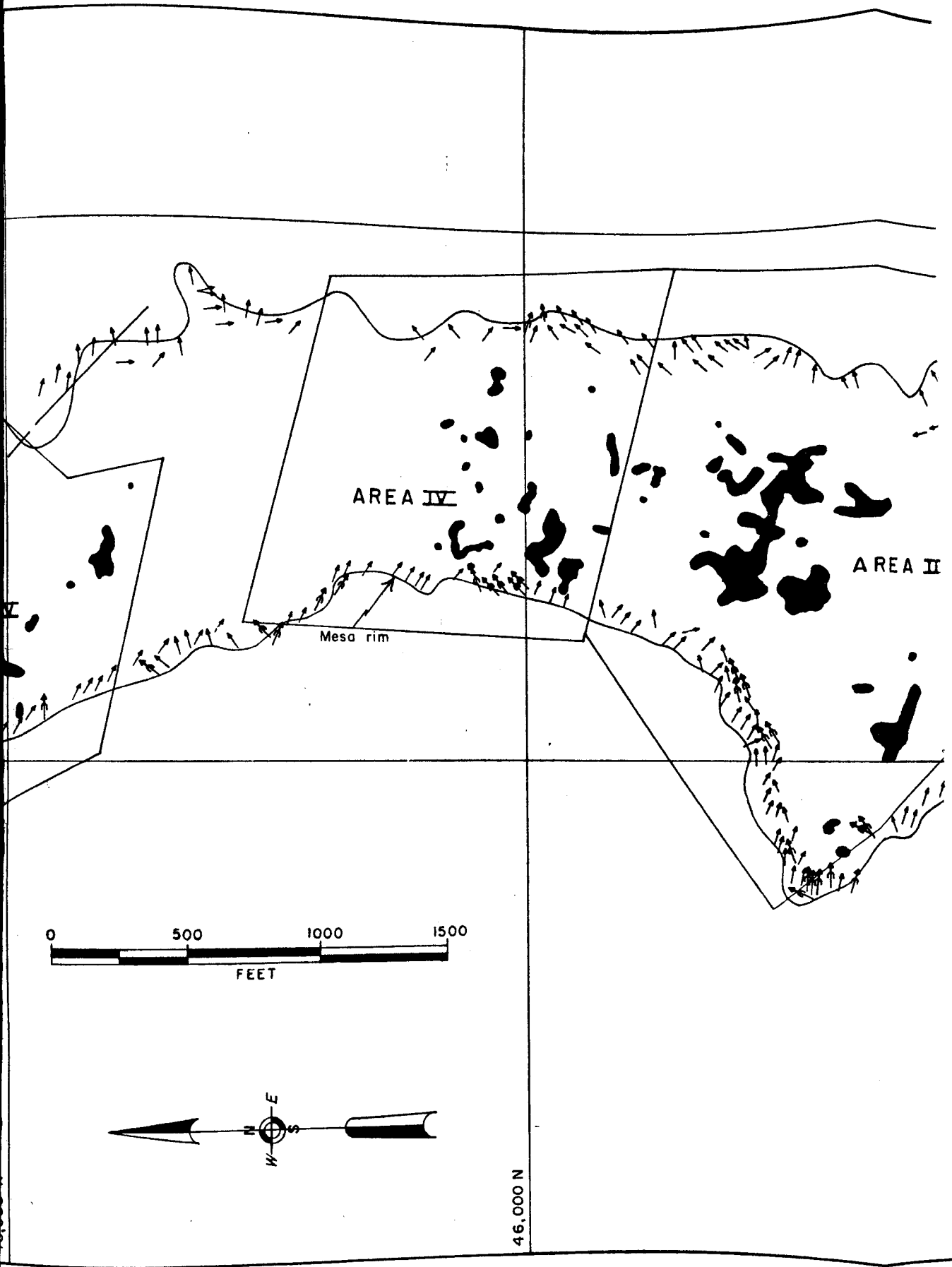
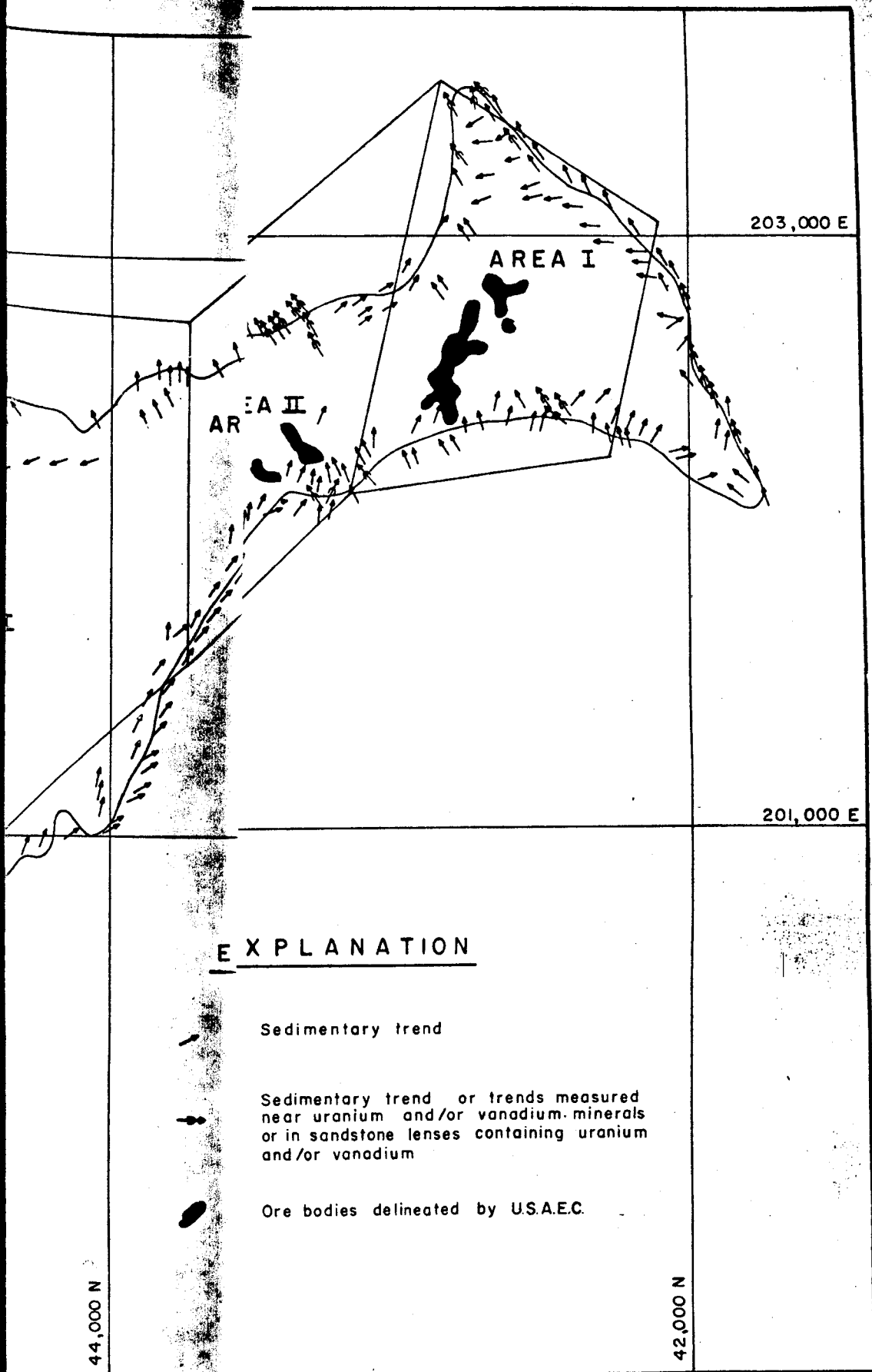


Figure 9. Ore bodies and sedimentary trends, Cove Mesa, Apache County, Arizona



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wagon holes were examined and the logs compared with the logs of the cored holes. Notations of color and thickness of thin units were seriously in error, owing to omission of thin claystone beds not apparent in the cuttings. Color contamination of sandstone was also noted, especially below red mudstone. The discrepancies were such that dependable subsurface lithologic logs could not be made from logs of these cuttings.

At normal wagon-drilling speed the examiner must log, on the average, 2 feet per minute. It is believed that this lack of time is a factor contributing to the inaccuracies of wagon drill logs. A slower drilling rate in holes drilled for stratigraphic information would allow the geologist adequate time in which to examine the cuttings. Another solution would be to have the samples preserved in their stratigraphic sequence for later examination.

To compare non-core assays from core, one-foot samples were taken through the ore and mineralized zones. As assays of these samples compared satisfactorily with the core assays, it was concluded that wagon drill cuttings gave accurate assay results.

SUMMARY AND CONCLUSIONS

The strata in the drilling areas dip from 2 to 3 degrees northwest. They contain ore in an interval between 20 and 100 feet above the base of the Salt Wash. The deposits range from small pods to tabular bodies as large as 600 by 150 feet. Thickness averages 2 feet, and average grade is 0.19 percent U₃O₈ and 1.40 percent V₂O₅.

In drilling of this type, when blocking-out of ore was desired, the best drilling guides were isorad maps of previous drilling projects and a rim map showing ore trends and sedimentary trends. The isorad maps indicated many areas of high subsurface radioactivity; the rim map located areas into which mineralized sands were trending from the rim. The trend map also suggested areas in which channel "meanders" might be found.

The Cove Mesa No. 3 project included 198 diamond drill holes, totalling 12,712 feet of drilling. Approximately 30 were ore holes, and 13 were mineralized but below ore grade. A total of 651 holes and 41,015 feet were drilled on the Cove Mesa No. 4 project. Of these, 156 were ore holes and 84 were mineralized but below ore grade.

The diamond drilling showed that favorable ground could be delineated using subsurface isorad maps based on holes drilled with 100-foot centers. Fifty-foot centers were found necessary to outline ore bodies. Wagon drilling proved satisfactory in testing favorable ground for the presence of ore and for outlining ore bodies. Lithologic logs made from the cuttings from wagon drill holes were unsatisfactory for precise subsurface maps.

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